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THE ORGANISM AND ITS ENVIRONMENT

By Dr. FRANCIS B. SUMNER

THE SCRIPPS INSTITUTE FOR BIOLOGICAL RESEARCH

THERE are times when we need to remind ourselves that the organism—the real organism, which lives and grows, and functions and acts, and in some cases thinks—is not an isolated phenomenon in nature, but is part of a complex system of interacting forces. It is utterly unintelligible, indeed we shall see presently that it does not even exist, except in organic relation to the outer world. Nevertheless, various trends in present-day biological discovery and speculation have confirmed us in the habit of viewing the living being as a distinct and independent entity, and of underrating the importance of a thorough knowledge of its environmental relations. Add to this the inevitable increase of specialization in all fields of science, which has tended to separate and to keep apart those whose studies relate chiefly to the isolated organism from those who are concerned primarily with its conditions of life and occurrence in nature. It is possible that these tendencies have already passed their zenith, and that the movement toward a greater measure of integration in biology is making satisfactory headway. But a perusal of the writings of those who form the dominant groups at the present time does not furnish much ground for this belief.

Let me be somewhat more concrete in regard to the causes which have led to this relative neglect of the environment by modern biologists. Morphology has for years, and perhaps unavoidably, confined itself to the study of preserved organisms, or more frequently of the excised organs or tissues of organisms.

Physiology—when it has broken away from medical bondage and asserted its rights as an independent science—has commonly studied the activities of animals or plants, or isolated parts thereof, under strictly “controlled,” *i. e.*, highly unnatural conditions. Taxonomy has dealt with collections of stuffed, pickled, pressed or otherwise preserved material. There has frequently been a rigid division of labor between the collector, who gathers and preserves the specimens, and observes them in nature, and the systematist, who studies and classifies them in his laboratory or museum, without such clues as are afforded by a knowledge of their local distribution, seasonal occurrence, life history, etc.

When we come to my own special field of genetics, this apotheosis of the organism and relative neglect of environmental factors is particularly evident. Strictly speaking, it is not even the organism here which is exalted into this position of well-nigh exclusive interest. It is that more or less imaginary entity, the "germ-plasm," which is conceived to flow on through the ages as an uninterrupted "stream," giving rise, at intervals, to ephemeral and relatively unimportant objects, the bodies of the individual organisms. Within broad limits, this "germ-plasm" is not supposed to be affected by the environment at all. It may, it is true, be killed by lack of food, extremes of temperature, or the like, or a particular "stream" of germ-plasm may at any time be brought to an untimely end by its failure to produce individuals which are adapted to their special conditions of life. But, aside from this process of selective elimination, the environment is not credited with the power of calling forth adaptive changes of a hereditary nature. Furthermore, many biologists are at present dubious as to whether environmental influences are capable of producing germinal changes of any sort, even those which result in the "mutations" upon which selection is supposed to act.

The great volume and the high importance of researches in Mendelian heredity during the past two decades have lead to a virtual identification of genetics with Mendelism. This statement applies not only to the rather confused notions of the layman, but to the deliberate utterances of the expert, who sometimes explicitly defines the word genetics in this restricted sense. Now Mendelism, as we all know, is concerned with the mode of transmission of certain more or less distinguishable "unit-characters" of the organism. These last, in turn, are supposed to be the visible manifestations of independent, indivisible, and in a high degree unalterable "factors" in the germinal substance. Occasional instances are cited, to be sure, in which particular unit characters depend for their manifestation upon particular conditions of the environment, and certain geneticists believe—usually as an article of faith—that unit factors may undergo "mutation" as the result of sufficiently potent changes in the external conditions. But, on the whole, the general effect of Mendelian studies has been to emphasize the isolation and independence of the organism—or at least, of its unit factors—and to minimize the importance of the environment, except as imposing limiting conditions to existence or growth.

After more than a generation of stalwart drubbing, Lamarckism is believed by most biologists to have yielded to the inevitable and to have gone to its last repose in an unhallowed grave. Not

only are individual acquirements believed to be incapable of hereditary transmission, but for man, at least, the rôle of external circumstances in the development of both body and mind, during the single lifetime, is frequently denied any very high importance. Environment—the “culture medium”—must furnish a certain low minimum of requirements for normal development. Beyond that, it is impotent to alter the preordained course of the individual life history.

The foregoing picture is not intended primarily as an indictment of recent biological philosophy. My chief object has been to point out some of the reasons for the relative neglect of the natural environment as an object of biological research. That the prevailing viewpoint which I have outlined above, is largely founded upon exact knowledge must, I believe, be admitted. That it represents an extreme position, and overlooks important lines of evidence, is to some of us equally clear. While I can not here enter into an extended justification of this last contention, I feel bound to indicate rather briefly the sort of facts upon which it is based.

In the first place, one can not overlook the utter bankruptcy of the Mendelian-Mutation scheme of things to account for evolution, and particularly to account for the origin of adaptive structures and functions.¹ Hereditary differences among organisms, according to this theory, depend upon the presence, in their respective “germ-plasms,” of somewhat different unit factors. Every natural species and most artificial races are known to be far from homogeneous in their hereditary make-up. As the result of selection—natural or artificial—individuals carrying certain favorable factor combinations may be perpetuated to the exclusion of others. As long as this process of sorting out is possible, the average character of the race may be altered in one direction or another. Sooner or later, however, we reach a condition in which all members of our selected strain possess the particular factor combination that insures the highest possible manifestation of the character for which we are selecting. In respect to these particular factors, our material has become homogeneous, and further progress along this line must cease.

Now, as a matter of fact, we all know that in some cases such progress has been continued indefinitely. We may point to abundant instances from nature, in which a tendency, once started, has been continued throughout ages of geologic time. The reduction

¹ One prominent geneticist, Heribert Nilsson, when confronted with the contradiction between the “facts” of Mendelism and the “theory” of evolution, escapes from his dilemma by casting the latter overboard! (*Festkrift Lunds Universitet*, 1918).

of the lateral toes of the horse's foot is an often cited example, which is as good as any. Certain breeding experiments, likewise, have shown the possibility of continuous modification throughout many generations. In some instances, this has occurred among the cultures of those who insist most strongly upon the truth of the "sorting out" conception of selection. Occasionally, too, there seems to be a sudden revival of the efficacy of the selective process, some generations after stability seemed to have been reached.

We are all familiar with the current explanation of these phenomena. Effective selection, in a race which has become homogeneous in respect to the factors concerned, is only possible through the occurrence of "mutations" or spontaneous changes in these factors. If such changes chance to occur in the same direction as the changes which were initiated by our selective process, the latter is given a new lease of life, until a condition of racial uniformity is once more established.

It is well to consider for a moment where such a conception leads us. There would seem to be nothing particularly mysterious in the fact that a race of organisms should undergo continuous changes in a given direction, as the result of "mutations," arising without any reference to environmental needs. Progressive changes are going on all about us in the inorganic world, some of these continuing for untold periods of time. What does need explaining is the fact that these changes, in the organic world, are so often in the direction of increasing adjustment to the conditions of life. Darwin's explanation of this fact—one which he felt obliged to supplement by another quite different explanation—is known to us as the theory of natural selection.

At the present day, there are probably as many estimates of the effectiveness of natural selection as there are biologists who are competent to express an opinion on the subject. All are probably agreed that it must be regarded as one of the factors of evolution. But most recent biologists are strongly impressed by various considerations which were either unknown to Darwin or were probably not sufficiently recognized by him. In the time allotted I can speak of only one of these. This is the inadequate supply of variations which are actually available as material for selection. At a time when most individual differences were believed to be more or less hereditary, and when practically no bounds had been set to the efficacy of the selection, it was much easier to assert the "all sufficiency" of this principle as the cause of progressive evolution. Even then, it must be remembered, there were many who denied the possibility that wholly random variations could furnish an adequate basis for evolution through natural selection.

In recent years, this difficulty has been magnified many fold. A large part of the variability of organisms, including many differences of survival value in the struggle for existence, are believed to be "somatic" or "phenotypic"—that is to say, non-hereditary. In respect to any given character, so much of the variability as is found to be inheritable is attributed to the action of relatively small numbers of unit-factors, which can be readily, and rather speedily, segregated in particular descent lines, if the degree of selection is rigid enough. Thus a very limited amount of permanent modification may be brought about fairly promptly. After that, we are forced to wait for the decidedly capricious process of mutation to help us further along the road.

One having a limited acquaintance with the discoveries of Morgan and his co-workers might be disposed to exclaim at this point: That is easy! New mutations are coming to light every day in the case of *Drosophila*. Would not this prove to be true with every race of organisms, if studied intensively?

I fear that such persons are leaning on a very frail reed. When we examine into the nature of these mutations of the fruit-fly, we find very little promising material for a theory of progressive evolution. Many of them are obvious deformities and abnormalities, not only in the sense of being departures from the typical condition, but in the sense of rendering the insects unfitted for life in nature. The body may be warped, the wings so abbreviated as to be useless, the legs duplicated or greatly shortened, the eyes reduced in size or suppressed altogether. Many of the mutant factors described by these authors belong to the class known as "lethals." That is to say, their presence in a homozygous condition results in the death—or failure to appear—of all the organisms so affected. Indeed, most of the mutant strains are distinctly less hardy, or more difficult to raise, than are flies of the wild type. The best that can be said for any of the modifications thus far appearing is that they are harmless to the organism. Those which are not positively deleterious consist in changes in the color of the body or eyes, in the number or form of bristles on the thorax, and other trivial departures from the normal condition. So far as I know, not a single one of these mutations—and there are some two hundred of them described—can be said to represent a better adapted type of organism. With a very few exceptions, they consist in obvious losses of structures or materials previously present.

We are not, of course, warranted in concluding from this that mutations of evolutionary value never occur. It is quite possible that they do. But what we actually know at present re-

garding such mutations as occur in our breeding cultures affords no safe ground for the belief that evolution has come about through the accumulation of these by natural selection.² This belief seems particularly difficult in the case of very slow breeding animals, such as the elephant, which have none the less undergone enormous structural modifications during relatively brief periods in the earth's history.

Here then is one difficult situation in which we find ourselves, if we follow the lead of the majority group of biologists in questioning the positive effectiveness of the environment as an agency in evolution. Are we not brought back to a viewpoint similar to that of Naegeli, who held "that animals and plants would have developed about as they have even had no struggle for existence taken place, and the climate and geologic conditions been quite different from what they actually have been?"³ According to Naegeli, the environment has had merely a pruning effect upon the tree of life, eliminating certain branches and permitting certain other others to grow. If this be the truth, we must, of course, accept it. But we should accept it on evidence, and not on authority.

That the environment may have had a far more positive influence upon evolution than is admitted by the Mendelian-Mutationist school of biology is further rendered probable by certain recent experiments. I refer particularly to the remarkable work of Guyer and Smith upon the inheritance of artificially induced eye defects in rabbits. The studies of these authors seem to prove conclusively that one particular class, at least, of "acquired characters" may be transmitted indefinitely from one generation to the next. And the mechanism by which these acquired characters seem to have been registered in the germ-cells is of a type which is conceivably operative on a large scale throughout the living world. I am waiting with interest to see whether the results of these remarkable experiments are to be explained away or robbed of their significance for biological theory.⁴

Another field in which this depreciative attitude toward the power of environment is at present conspicuous is that of eugenics and the study of character formation in man. Since I have recently

² Professor Bateson, who is usually regarded as a pioneer "mutationist," has recently declared (*SCIENCE*, January 20, 1922) that "we have no reason to suppose that any accumulations of characters of the same order" [*i. e.*, "transferable" or segregating ones] "would culminate in the production of distinct species."

³ Kellogg (*Darwinism Today*, p. 278).

⁴ For present purposes it is immaterial whether these phenomena be attributed to "parallel induction" or to "somatic induction."

published a special article on this subject,⁵ I shall take the liberty of quoting rather extensively from this. My first object in the article referred to was to point out the very general confusion which exists regarding the relations between heredity and environment in human development.

"Every 'character' (whether we mean by this word a bodily part or organ, or a trait or mental disposition) has a hereditary basis. Likewise, every character is due, in its final state, to the interaction of this hereditary basis with other parts of the developing body, and with the sum-total of external conditions, physical and biological, which we call the 'environment' of the organism.

"However, it seems quite proper to speak of *differences* between two organisms as due solely to heredity or solely to environment. Thus plants of different stock, reared under identical environments, might differ greatly in size or in other respects. These differences would be of purely germinal origin. On the other hand, two plants of identical heredity might be reared in different soils and come to differ widely in size or otherwise. Such differences would be purely environmental.

" The familiar question, Which is the more important, heredity or environment? is not capable of answer when stated in that form. One might as well ask, Which are the more important in the construction of a house, the building materials or the carpenters? We may, however, as just indicated, frame the question in another way: Are the *differences* which we observe among our fellow men due chiefly to *differences* of heredity or to *differences* of environment, using the last term in its broadest sense?⁶ Even here, we must be more explicit. Do we refer to the differences between the white man, the Chinaman, and the negro, or do we refer to the differences which we observe among individuals of the same race? The differences between the various races would be granted by most persons to be hereditary. But the differences within a given race are regarded by many as being due, in large degree, to the circumstances of life—to feeding, home surroundings and 'bringing up.' This is claimed particularly for the mental and moral characteristics."

"Francis Galton, after reviewing the evidence derived from the study of identical twins, thus expresses his belief regarding the relative potency of heredity and environment in determining human differences: 'There is no escape from the conclusion that nature prevails enormously over nurture, when the differences of nurture do not exceed what is commonly to be found among persons of the same rank in society and in the same country.'

"And truly, I do not see how we can escape this conclusion, if we bear in mind Galton's reservation. . . .

"I think it likely, however, that many recent geneticists, especially some of those who are active in the eugenics movement, would throw out Galton's reservation and insist that 'nature prevails enormously over nurture' in determining the mental and moral differences among an entire population, regardless of its social strata.

"The opposite, or 'environmentalist' philosophy, in its extreme form,

⁵ Heredity, environment and responsibility. Bulletin of the Scripps Institution, No. 10, July 2, 1921.

⁶ See Popenoe and Johnson, "Applied Eugenics," p. 3.

would assert that almost any individual may be given almost any type of physique, intellect, or moral character, if taken sufficiently early and subjected to a proper regimen during the period of growth and character formation. . . .

"It is my own belief that the scientific geneticists and eugenicists are much nearer the truth than the mere undisciplined lovers of mankind, but that they have been led into a somewhat extreme position by their efforts to square the facts of life with certain biological theories. Now there are various considerations of a strictly scientific nature which would seem to establish the presumption that non-inherited factors in the formation of human character should be given more weight than is frequently accorded them by biologists."

The time at my disposal does not permit of an adequate discussion of these considerations. I shall restrict myself to a brief mention of one of them. This is the probability, admitted by most biologists, that civilized man has undergone little if any improvement in his inherent mental make-up since the dawn of history.

While it is not necessary to admit such extreme claims as have been made by some biologists, I think there is no escape from the conclusion that mankind, or the civilized part of it, has made *little* advance in potential brain power during the entire period of history—little in comparison with his racial achievements in science, philosophy, art, invention, morals, etc. In other words, human progress has been extrinsic rather than intrinsic. We have built up an enormously complex world of racial acquirements, consisting of customs, laws, and knowledge, as well as all the physical paraphernalia of civilization.

Thus, if it is really true that the innate brain power of mankind has undergone little or no increase since paleolithic times, the higher mental status of the modern man is due almost wholly to a fuller development in each of our lives of potentialities which were present in the man of the Old Stone Age. This, of course, is but another way of saying that even such enormous differences as distinguish a Cro-Magnon cave-dweller from a modern European are chiefly, if not wholly, environmental.

It may be worth while, in the interests of clear thinking, to undertake an analysis of this distinction which we are so prone to draw between organism and environment. How far is this antithesis a real one, and how far is it a mere matter of convenience? Let us consider this question, first of all, in its bearing upon the science of genetics.

The sum-total of causal agencies which result in the production of a complete organism from a fertilized ovum are commonly grouped under two heads: (a) the material constitution of the fertilized ovum itself, particularly of its chromosomes; and (b) external influences which act upon the developing organism, from

the moment of fertilization to the close of the life cycle. This classification corresponds in the main to the familiar antithesis between heredity and environment, nature and nurture. As a matter of fact, the distinction thus drawn is largely a chronological one, the influences acting before fertilization being lumped together along with "nature," those acting after that event being assigned to "nurture." If we insist that heredity relates only to the "intrinsic" factors in the situation—to the material constitution of the "germ-plasm" independent of environmental influence at *any* period—it seems to me that we are dealing with something purely imaginary. There never is a period in the history of the germ-cells or their forerunners when they are not vitally dependent upon their living environment. Every step in their history involves an interaction between certain factors which may be called "intrinsic" and other factors which are external to these. What is "intrinsic" at one moment may have been "extrinsic" the moment before. Whether this relation is of a type which makes possible the form of inheritance assumed by Lamarck is a question which we need not consider here. I merely wish to point out that no hard and fast distinction can be drawn between heredity and environment as conditioning the life of an organism. The distinction is largely one of chronology, and the moment of demarcation between the two must be chosen rather arbitrarily. In practice, to be sure, the distinction implied by these words is in the highest degree useful. But we should not imagine that it is an absolute one.

It may be of interest to carry this analysis a step further. I am prepared to defend the somewhat paradoxical thesis that the organism and its environment constitute an inseparable whole; that if we could detach all environmental elements from this complex there would be no organism left. Nor do I intend this as a mere bit of Hegelian dialectic. A moment's reflection serves to show that we can draw no sharp line of division, not even a theoretical one, between the two.

If I should ask you whether the nest of a bird constituted a part of the organism or a part of its environment, I presume that every one present would resent the question as an insult to his intelligence. Nor would there probably be any hesitation if the question related to the patch-work dwelling of a caddis-worm, even though this dwelling is carried around by the larval insect, as if it were an integral part of its body.

The situation becomes somewhat less clear, perhaps, when we consider the calcareous tube of a marine annelid. Here is something which is definitely secreted by the epidermal cells of the organism,

and which forms a sort of permanent integument. It does not, however, in this case, retain any organic connection with the body of the worm. But when we pass to the shell of a mollusk we find that there is such an organic connection with the body, so that the animal cannot be dislodged without extensive injury to its living tissues. Moreover, the purely mineral ingredients of the shell are sandwiched in between layers of a substance which we commonly speak of as "organic," though not in this case as living. Does such a shell belong to the organism or to its environment?

If there be any doubt in the case of the mollusk, let us consider the bony carapace of the tortoise. This, likewise, is composed in part of mineral salts, in part of equally lifeless "organic" materials, produced through the metabolism of living matter. But in addition to these lifeless elements, we here encounter a multitude of living cells contained in minute spaces scattered throughout the bony substance; and even blood-vessels and nerves, which provide for the nutrition and growth of these cells. All persons would probably agree that such an exoskeleton belongs to the creature's body.

Let us pass next to a consideration of the internal fluids which are concerned with distributing food and oxygen to the living tissues and with carrying away their waste products. Perhaps a reversal of the order previously followed would here be instructive. In the case of vertebrates, the blood is itself commonly classed among the tissues of the body. Cells of several kinds are present, along with a fluid, intercellular matrix consisting, in large part, of proteid substances, approaching in complexity those which compose the "protoplasm" of the living cells.

Among the mammals, the blood maintains a high degree of constancy in its composition, regardless of changes in the external medium. A seal or a porpoise may pass from fresh to salt water, or vice-versa, without undergoing any change in the concentration of the blood. This is not true, however, of the fishes. Those which are capable of living equally well in fresh and salt water show a higher salt content in the latter than in the former.

Now among fishes—or at least the bony fishes—this concentration of salts in the blood is not proportional to that of the water in which they happen to be. But the case is quite different with many marine invertebrates. As a result of osmosis and diffusion both the concentration and composition of the salts in the body fluids of such animals is rapidly brought into conformity with that of the water in which they are placed.

In the coelenterates, it is well known that the gastrovascular cavities and their contained fluids are in direct connection with the

surrounding ocean, while in the sponges the only circulating medium is the sea-water itself, which is propelled through multitudinous canals by the motion of the flagella. Once more, is it not obvious that the distinction between organism and environment is a conventional and arbitrary one?

This line of argument would be quite incomplete without reference to the transformations which constitute that most characteristic process of living matter, metabolism. Unfortunately, my limited knowledge of biochemistry would not make it possible for me to discuss the subject adequately even if my allotment of time permitted. But even such slight knowledge as I do possess enables me to assert with confidence that there is no definite point in the process at which we can say for the first time: This is no longer food; it has become living matter. Nor, on the descending phase of the metabolic cycle, is it possible to distinguish the moment at which the living passes over into the non-living. But food and waste matters belong to environment. They can hardly be regarded as parts of the organism.

In short, the organism and the environment interpenetrate one another through and through. The distinction between them—let me repeat—is only a matter of practical convenience. Should not such considerations affect our attitude toward the propriety of neglecting the environment as an object of biological research? I make no pretense, of course, that such neglect is universal. An active and important group of present-day biologists is giving its chief attention to the organism-environment complex. My criticisms—so far as I have made any—relate to general tendencies and average conditions, and these have not, I believe, been unfairly portrayed.